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Radiation Pattern Measurements of the Expanded Very Large Array (EVLA) C-Band Feed Horn in the MIT Lincoln Laboratory New Compact Range: Range Validation at 4 GHz

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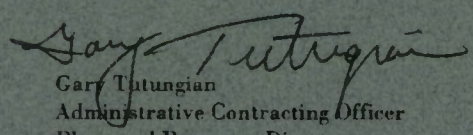

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Radiation Pattern Measurements of the Expanded Very Large Array (EVLA) C-Band Feed Horn in the MIT Lincoln Laboratory New Compact Range: Range Validation at 4 GHz

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ABSTRACT

The National Radio Astronomy Observatory is developing and installing several new feeds and receivers on the expanded very large array (EVLA) antennas in New Mexico. Antenna pattern measurements of the EVLA C-band feed horn in a new compact range reflector system at MIT Lincoln Laboratory are described in this report. Measured and calculated antenna radiation patterns of the EVLA C-band feed at 4 GHz are in good agreement.

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1. INTRODUCTION

The very large array (VLA) is a synthesis radio telescope operated by the National Radio Astronomy Observatory (NRAO) that is located 60 miles west of Socorro, New Mexico on the plains of San Augustin. In operation since 1980, the VLA is a Y-shaped array of 27 shaped Cassegrain reflector antennas (shown in Figure 1) [1]. The reflector antennas of the VLA are on rails and can be moved to configurations in which the length of the Y-shaped arms is 600 m, 1.8 km, 4.6 km, or 21 km. Each of the mechanically-steered reflector antennas has a 25-meter diameter main reflector—the total effective aperture for the 27 dishes is approximately 13,000 m^2. Feed antennas at the VLA include prime focus crossed dipole feeds at 75 MHz and 308–343 MHz, and off-axis horn feeds at 1.35–1.73 GHz, 4.5–5.0 GHz, 8.0–8.8 GHz, 14.4–15.4 GHz, 18–26 GHz, and 40–52 GHz. The off-axis feeds and receivers are mounted on the reflector antenna surface in a circle around the primary reflector axis. A change in frequency band is accomplished by rotating the asymmetric subreflector to position the secondary focus on the desired feed. NRAO is currently involved in the Expanded Very Large Array (EVLA) Project [2] incorporating replacement of the existing electronics with state-of-the-art equipment and possibly adding eight new stations which will improve the continuum sensitivity of the array by a factor of 5 to 20. The eight new reflector antennas will be located up to 300 km from the current VLA.

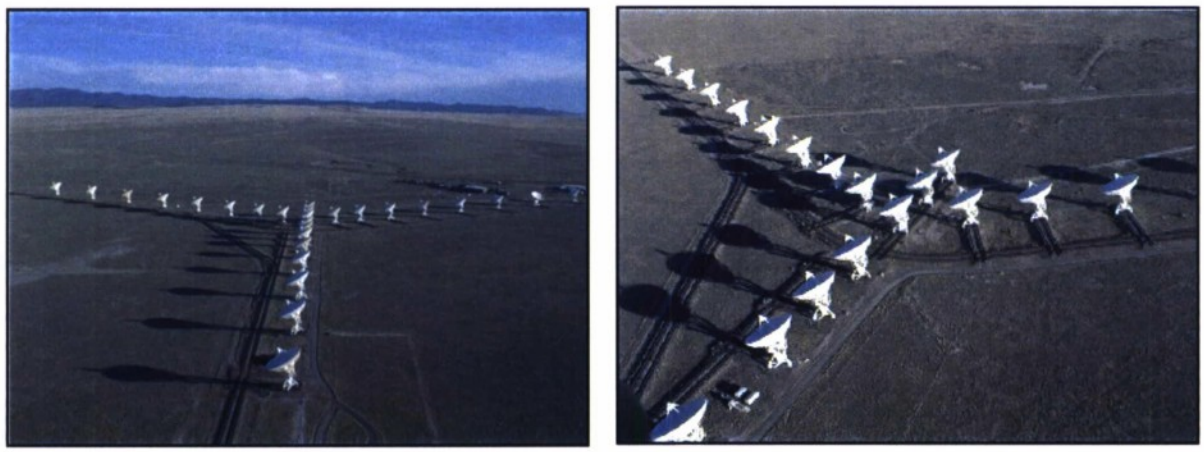

Figure 1. Two views of the VLA located in New Mexico. The array of 27 dish antennas is in the process of being expanded to 35 dishes.

In Phase I of the development of the EVLA, there will be eight frequency bands: L- (1–2 GHz), S- (2–4 GHz), C- (4–8 GHz), X- (8–12 GHz), Ku- (12–18 GHz), K- (18–26 GHz), Ka- (26–40 GHz), and Q-band (40–52 GHz). All of the feed horn antennas for the 1–52 GHz continuous band will be located at the secondary focus of the Cassegrain reflector. In Phase II, besides the addition of eight new antennas, prime focus feeds spanning 300 MHz to 1 GHz are planned.

NRAO recently completed the development of the C-band EVLA feed horn. Prior to the installation, alignment, and evaluation of this feed horn at the VLA, it was necessary to measure the radiation patterns and phase center of the antenna; however, NRAO antenna test facilities were not available due to scheduled maintenance. MIT Lincoln Laboratory, a federally funded research and development center (FFRDC), recently completed a new compact range facility at Hanscom Air Force Base in Lexington, Massachusetts, which was suitable for the desired antenna testing. The NRAO C-band EVLA feed horn was provided on loan to MIT Lincoln Laboratory as government furnished property, which allowed a unique opportunity to validate the new compact range measurements capability at C-band by comparison of measured and computer simulated feed horn radiation patterns.

2. EVLA C-BAND FEED HORN AND MIT LINCOLN LABORATORY COMPACT RANGE TEST FACILITY

An outline drawing of the NRAO C-band corrugated conical feed horn is shown in Figure 2. The horn has a 24-inch aperture and a length of 66 inches. Computer simulated patterns and estimated phase center positions of this horn antenna were calculated using a mode-matching technique.

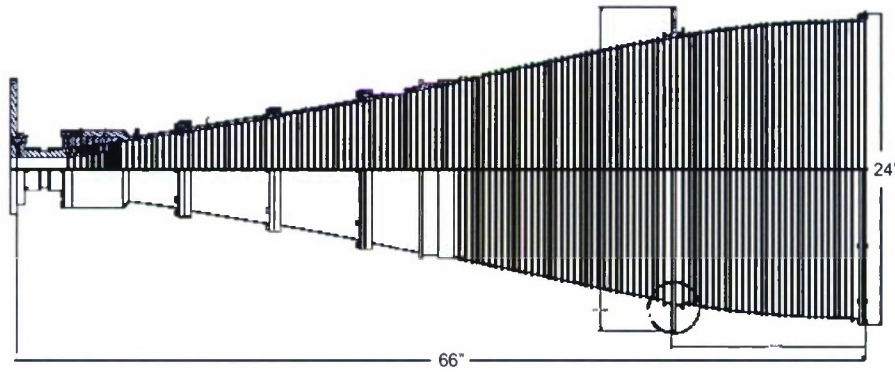

Figure 2. Drawing of the EVLA C-band feed horn.

A conceptual diagram of the new MIT Lincoln Laboratory compact range facility [3] is shown in Figure 3. The compact range began an initial operating capability for antenna testing in August 2004. The compact range is one of four new anechoic chambers in the RF system test facility located in a hanger at Hanscom Air Force Base. The compact range facility utilizes an offset-fed 24 × 24 foot rolled edge reflector and a series of antenna feeds that support measurements of both antennas and radar cross section of targets up to 12 × 12 × 12 feet over the frequency band 400 MHz to 100 GHz. A gantry/crane is used to bring antennas and targets into the chamber. A feed horn at the focal point of the reflector illuminates the rolled edge reflector which generates the desired plane wave in the test zone. For the NRAO C-band feed horn measurements, an MI-Technologies antenna model tower (fiberglass, 30-inch diameter) with positioners (upper polarization over azimuth, MI-Technologies model 53230B, and lower azimuth over elevation, MI-Technologies model 53450B) was used to support, position, and rotate the test antenna as desired. A motorized 6-foot linear slide was mounted on top of the lower azimuth over elevation positioner. For these measurements, a linearly polarized wideband 2–18 GHz feed horn (BAE, Model H-1498) was used to feed the compact range reflector. A photograph showing the installation of the EVLA C-band feed horn on the antenna positioner is shown in Figure 4. The center of the EVLA feed horn was located approximately 19.5 feet above the floor of the chamber near the center of the quiet zone. The microwave measurements were made using a Hewlett-Packard model 85310 antenna measurements system (8530 receiver-based). Antenna positioning was accomplished using an MI-Technologies model 4192 position-control system.

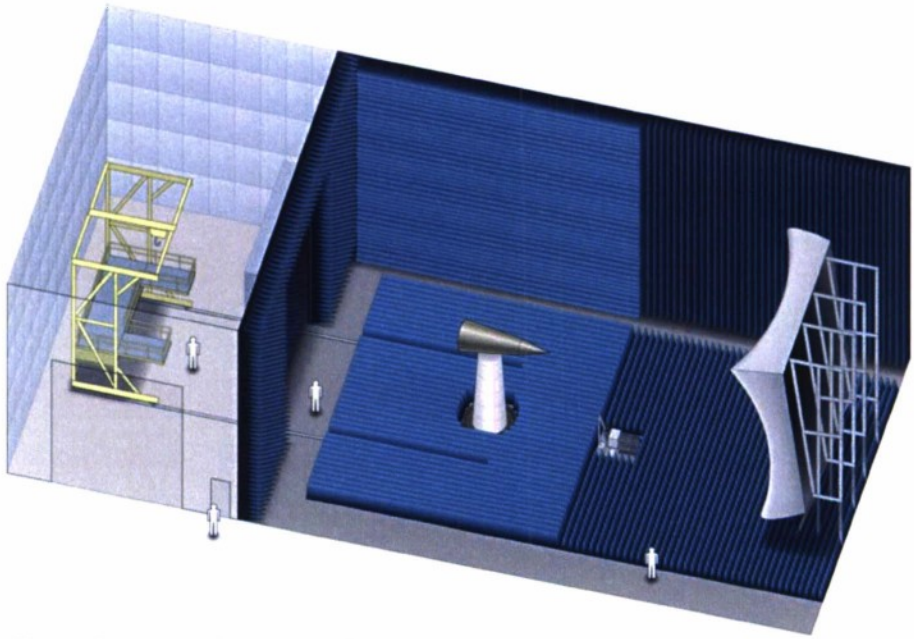

Figure 3. Artist's depiction of the new MIT Lincoln Laboratory compact range system.

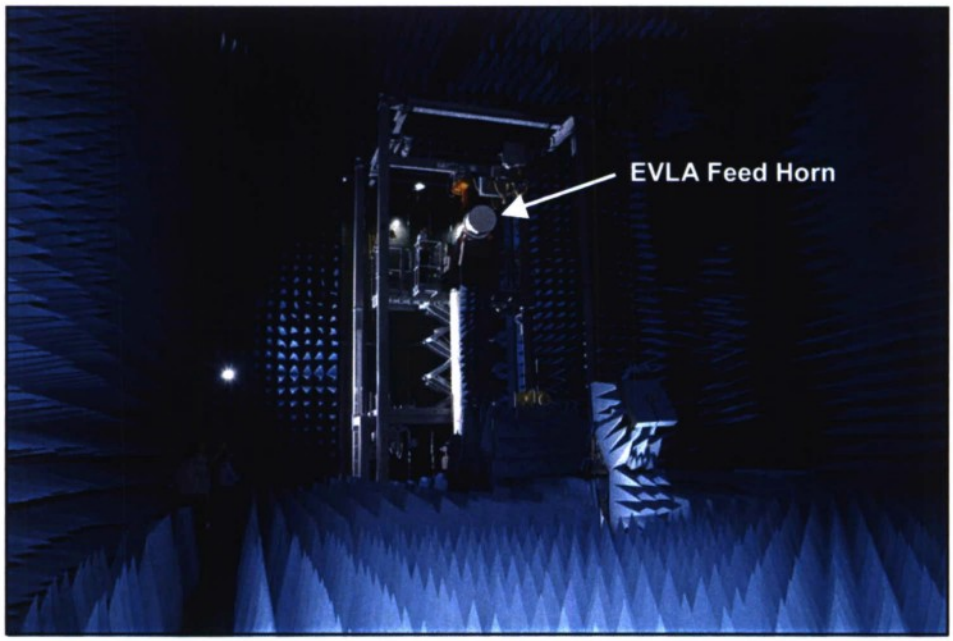

Figure 4. Photograph showing the NRAO EVLA C-band feed horn being installed on the antenna positioner in the new MIT Lincoln Laboratory compact range facility.

3. RESULTS

3.1 FEED HORN TEST SETUP

Figures 5a–c shows photographs (front, rear, and side views) of the EVLA C-band feed horn installed in the compact range chamber. An NRAO-provided microwave transition was used to connect to the rear flange of the feed horn. The upper polarization over elevation positioner was set to a fixed orientation during these tests. The horn was attached to the upper polarization plate by means of straps connected to a wedge-shaped adaptor plate. By loosening and then tightening the straps, the horn was rotated (rolled) manually to measure either the E-plane or H-plane patterns.

Figure 5. Photographs of the EVLA C-band feed horn installed in the new MIT Lincoln Laboratory compact range; (a) view looking toward the rear of the compact range chamber, (b) view looking from behind the feed horn toward the compact range reflector, and (c) side view of feed horn on the antenna positioner.

Figure 6 shows a detailed view of the antenna under test in the compact range chamber. The C-band horn was aligned using the upper elevation positioner so that the horn aperture was vertical. The lower slide was used to adjust the axial position of the center of rotation of the horn to be as close as possible to the computer simulated phase center position. The microwave receiver recorded the amplitude and phase as the feed horn was rotated in azimuth using the lower azimuth antenna positioner. H-plane

patterns were collected with the feed horn vertically polarized. Similarly, E-plane patterns were measured with the feed horn horizontally polarized. Both co-polarized and cross-polarized patterns in the 45-degree plane were also recorded.

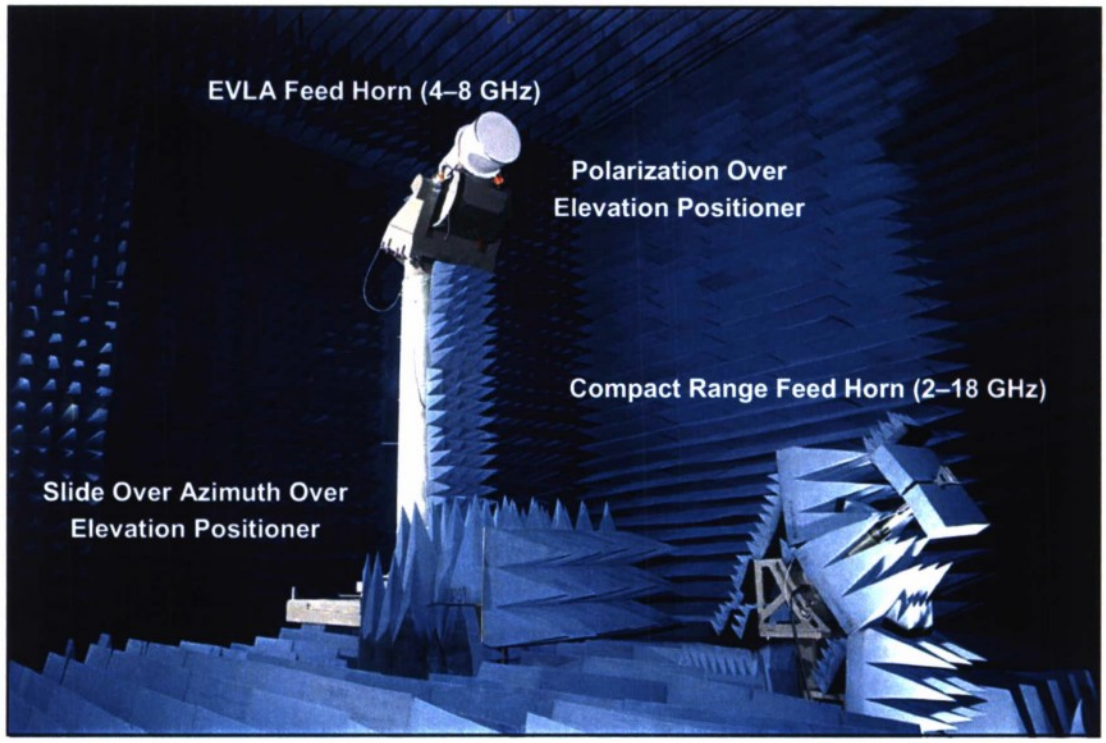

Figure 6. Test setup for pattern measurements of the NRAO C-band feed horn in the new MIT Lincoln Laboratory compact range.

3.2 COMPARISON OF MEASURED AND COMPUTER SIMULATED RADIATION PATTERNS AT 4 GHZ

As mentioned in Section 2, prior to radiation pattern measurements at MIT Lincoln Laboratory, a mode matching electromagnetic model (EM) of the C-band EVLA feed was developed at NRAO. The EM model was used by NRAO in designing the feed and in calculating the antenna radiation patterns and phase center positions. Measured radiation pattern cuts were recorded over a range of angles −120 to 120 degrees in one-degree increments.

The compact range measured and mode-matching simulated radiation patterns at 4 GHz are shown in Figure 7 (H-Plane) and in Figure 8 (E-Plane). The measured and simulated data for both H and E planes are in good agreement down to about the −50 dB level. This comparison provides an initial validation of the new MIT Lincoln Laboratory compact range antenna measurements system.

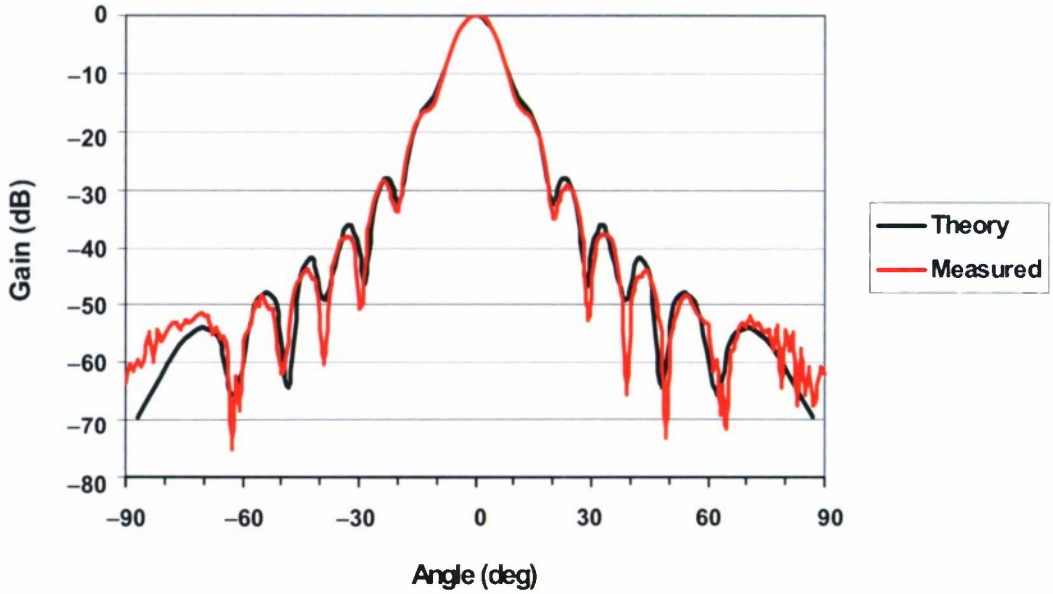

Figure 7. Comparison of measured and calculated H-Plane antenna radiation patterns for the NRAO C-band feed horn at 4 GHz.

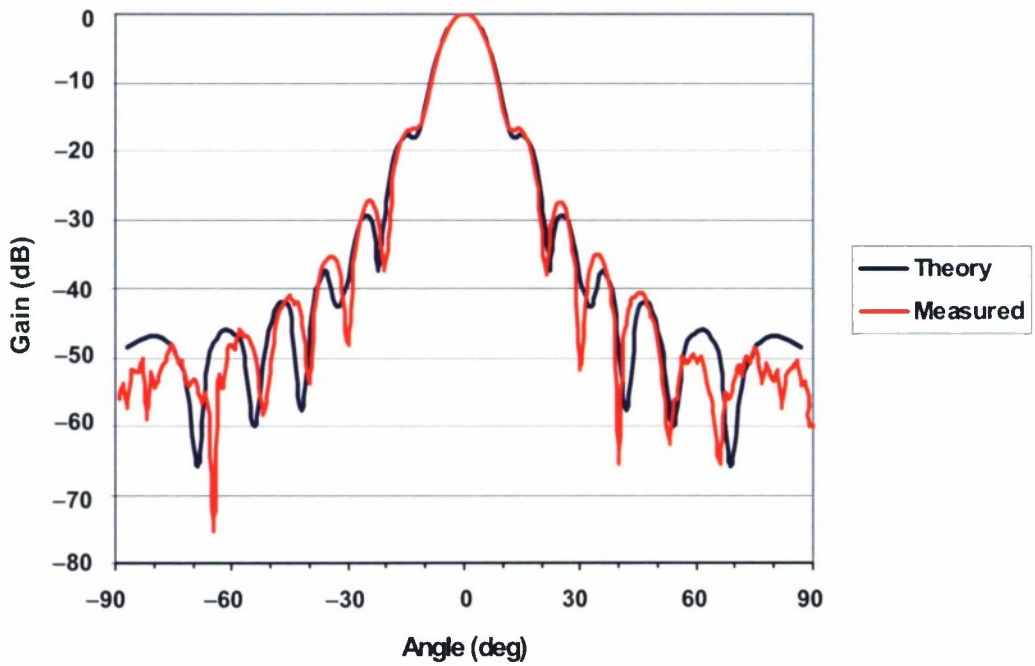

Figure 8. Comparison of measured and calculated E-Plane antenna radiation patterns for the NRAO C-band feed horn at 4 GHz.

4. CONCLUSIONS

A comparison of compact range measured and simulated radiation pattern data for the EVLA C-band feed horn at 4 GHz has been completed and the data are in good agreement. Thus, these data demonstrate that antenna pattern measurements with the new MIT Lincoln Laboratory compact range reflector, feed, antenna positioning system, and RF instrumentation are accurate. Measured phase center data will be used in the initial alignment of the C-band feed horn when it is installed at the EVLA site.

The measurements described in this report provide an initial validation of the RF measurement accuracy of the new compact range system at C-band. Further validation of this new compact range facility using other well characterized antennas at other frequencies is planned.

REFERENCES

1. P.J. Napier, "The Large Synthesis Radio Telescopes of the National Radio Astronomy Observatory," *1992 IEEE MTT-S International Symposium Digest*, Vol. 3, pp 1243–1246 (1–5 June 1992).

2. M.P. Rupen, "The Very Large Array Expansion Project," *Proc. SPIE*, Vol. 4837, Part 1, 2003, pp 119–128 (22–26 August 2002).

3. A.J. Fenn, M.W. Shields, and G.A. Somers, "Introduction to the New MIT Lincoln Laboratory Suite of Ranges," Antenna Measurement Techniques Association Meeting, Stone Mountain Park, Georgia, pp 37–41 (17–22 October 2004).

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